Holocene Palaeoenvironmental Reconstruction Based on Microfossil Analysis of a Lake Sediment Core, Nong Han Kumphawapi, Udon Thani, Northeast Thailand

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FEW LATE QUATERNARY palynological studies exist for continental Southeast Asia. This is despite the fact that there is good potential for the interpretation of former environments through palynological techniques, with the considerable physiographic and climatic diversity of the region reflected in discernible floristic patterns in the existing landscape. The potential scientific value of such studies is clear given the geographical significance of the region in terms of both climate, particularly with regards to the influence of the tropical monsoon belt, and archaeology, with intensive research in recent decades into the Holocene development of centers of habitation and agriculture.

Most published Holocene palynological studies in Thailand derive from lowland and coastal sites in southern and central parts of the country, with few available for inland northern regions. Detailed coastal and near-coastal studies include those at Chanthaburi in southeast Thailand (Pramojanee and Hastings 1983), Satingpra (Stargardt 1983) and Narathiwat in peninsula Thailand (Hastings 1983), and Khok Phanom Di (Maloney 1991) and Senanivate Pit (Sangsuwan et al. 1987) on the southern Central Plain. These pollen records indicate local environmental effects of Holocene sea-level change on vegetation communities, largely interpreted from fluctuations in the representation of pollen from mangrove communities, and confirm the last sea-level transgression for the Gulf of Thailand as recently as 3000 years Before Present (B.P.). Attempts to reconstruct palaeoclimates in the north and northeast of Thailand are far less common. The only site to provide a continuous Holocene pollen record is Doi Inthanon, northern Thailand, from a small peat bog around 2500 m above sea level (ASL) (Hastings and

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Liengsakul 1984). The pollen record derived from this site indicates the replacement of pine forest by wet-evergreen forest around 4000 B.P., perhaps indicative of a change to moister climatic conditions in response to the sea-level transgression. Indeed, a range of regional studies and modeling suggest increased regional precipitation and runoff in Southeast Asia in the early to mid Holocene (see Bishop and Godley 1994).

Clearly, there are few detailed palaeoecological studies within Thailand, and little is therefore known conclusively about Holocene climate change in the region. This paper presents preliminary pollen, phytolith, and charcoal analyses of a lake sediment core from Nong Han Kumphawapi on the Khorat Plateau, northeast Thailand, in an attempt to clarify the palaeoclimates and human occupation of the region; a subsidiary aim is to identify the onset and development of rice agriculture. We first provide an archaeological framework for our study.

ARCHAEOLOGY AND THE ORIGINS OF RICE AGRICULTURE

The Holocene archaeology for the Khorat Plateau is described in detail by Higham (1989), Bayard (1984), White (1986), Peng (1990), Kijngam et al. (1980), Higham and Kijngam (1984), and others. Bayard (1984) proposed a cultural framework for northeast Thailand that has been widely used. The period dating from approximately 5000 B.P. to the present, which incorporates all the available archaeological data for northeast Thailand, is divided into four periods: General Periods A–D. Each period is characterized by specific cultural indicators, representative of a phase of cultural development, based on archaeological remains and radiometric dating. This chronology reflects the absence of archaeological data prior to the emergence of domestic communities in the northeast. This may indicate mid-Holocene migration onto the Khorat Plateau, rather than a long period of cultural development in situ (Higham and Kijngam 1979).

A recurring theme in the study of the prehistory of the Khorat Plateau has been the nature of subsistence strategies employed by the earliest settlers, with a particular emphasis on the role of rice utilization within these strategies. The north and northeast of Thailand are thought to lie within Chang's (1976) genetic "homeland" of domestic rice, and dates for an early use of rice in Thailand were established from sites such as Spirit Cave (c. 7000 B.P.; Gorman 1970), Ban Chiang (c. 3500 B.C.; Higham and Kijngam 1979), and Khok Phanom Di (c. 4000 B.P.; Kealhofer and Piperno 1994; Maloney 1991).

Palynology has been unsuccessful in attempting to trace the origin and development of rice agriculture. Pollen from the cultivated rice *Oryza sativa* L. is indistinguishable from other species within the genus, and indeed other genera within the family Poaceae. Attempts to categorize grass pollen, and more specifically to identify an "*Oryza* type," are legion (Bennani et al. 1984; Andersen and Bertelsen 1972; Driessen et al. 1989; Kohler and Lange 1979; Maloney 1989; Salgado-Labouriau and Rinaldi 1990). In most cases, size measurements and exine sculpturing are used to discriminate between broad morphological groups, but these classifications are often difficult to apply to standard light-microscopes. While these morphological groups have been applied in palaeoenvironmental studies (Maloney 1991; Tsukada et al. 1986), they often represent several taxa, and therefore their ecology cannot be precisely defined. Furthermore, it has been clearly shown that pollen from naturally occurring wild rice cannot be distinguished from that of the cultivar (Maloney 1989).

Despairing of grass pollen, researchers have attempted to identify palynologically distinctive taxa that have strong ecological associations with rice fields and rice cultivation (Heckman 1979; Maloney 1984; Maloney et al. 1989; Maloney 1991). The majority of taxa known to occur in rice fields are either sedges or grasses, which are difficult to differentiate palynologically to genus level. Maloney et al. (1989) have suggested that rice-field weeds such as *Ludwigia octovalis, Nymphoides indicum, Ceratopteris thalactroides, Scirpus* spp., and Commeliniaceae could provide circumstantial evidence of rice cultivation. White (1995), however, has suggested that rice cultivation represents an expansion of a natural ecological niche, rather than the creation of a biologically distinct ecosystem. Certainly, most plants occurring in rice fields as weeds will also occur in the shallow marginal areas of lakes and swamps, and one might therefore expect their presence in the microfossil records taken from these sites with or without rice cultivation.

An additional problem associated with using palaeoenvironmental techniques to identify periods of rice agriculture is that lake sites, which are ideal for palaeoenvironmental analyses, may not have been favored by the earliest occupants of the Khorat Plateau for the cultivation of rice. White (1995) has suggested that stream-side locations were more suitable for the initial collection and perhaps cultivation of rice given the greater ease with which water resources may be manipulated in these areas. Indeed, archaeological surveys of the Kumphawapi region, northeast Thailand (Higham and Kijngam 1984; Kijngam et al. 1980) suggest relatively late settlement in the immediate vicinity of the Lake Kumphawapi (c. A.D. 800; Kijngam et al. 1980 : 20). Pending the discovery of early settlements in the vicinity of natural lakes in the northeast, it may be argued that lake sites are not likely to provide clear evidence of the early human manipulation of the local flora. Rather, changes in regional vegetation communities indicated in the fossil pollen assemblages are likely to provide less equivocal evidence of human activity in the catchment than will changes in the local flora. However, the ability to relate catchment disturbance through clearing and burning to rice cultivation, while making a good deal of intuitive sense, is untested, and therefore evidence of this nature should be evaluated cautiously.

REGIONAL SETTING

The Khorat Plateau, northeast Thailand (Fig. 1), encompasses an area of approximately 156,600 km^2 (Arbhabhirama et al. 1988). It is bounded to the north and east by the Mekong River, to the west by the Petchabun Range, and to the south by the Dangrek Range. The ranges consist of flatbedded sandstone, with higher peaks exceeding 1200 m ASL. Plateau altitudes generally lie in the range from 120 m to 220 m ASL (Thiramongkol 1983), though local relief rarely exceeds 25 m (Parry 1990). The plateau encompasses two shallow basins, the larger Khorat Basin to the south and the smaller Sakon Nakhon Basin to the north. Two principal rivers, the Mun and the Chi, drain the region to the southeast. The Khorat Plateau is thought to be the result of Mid-Tertiary and possibly Quaternary epeirogenic warping (Thiramongkol 1983). Volcanism and uplift may have occurred as recently as the middle Pleistocene (Parry 1990; Moore 1988; Wongsomsak 1987).

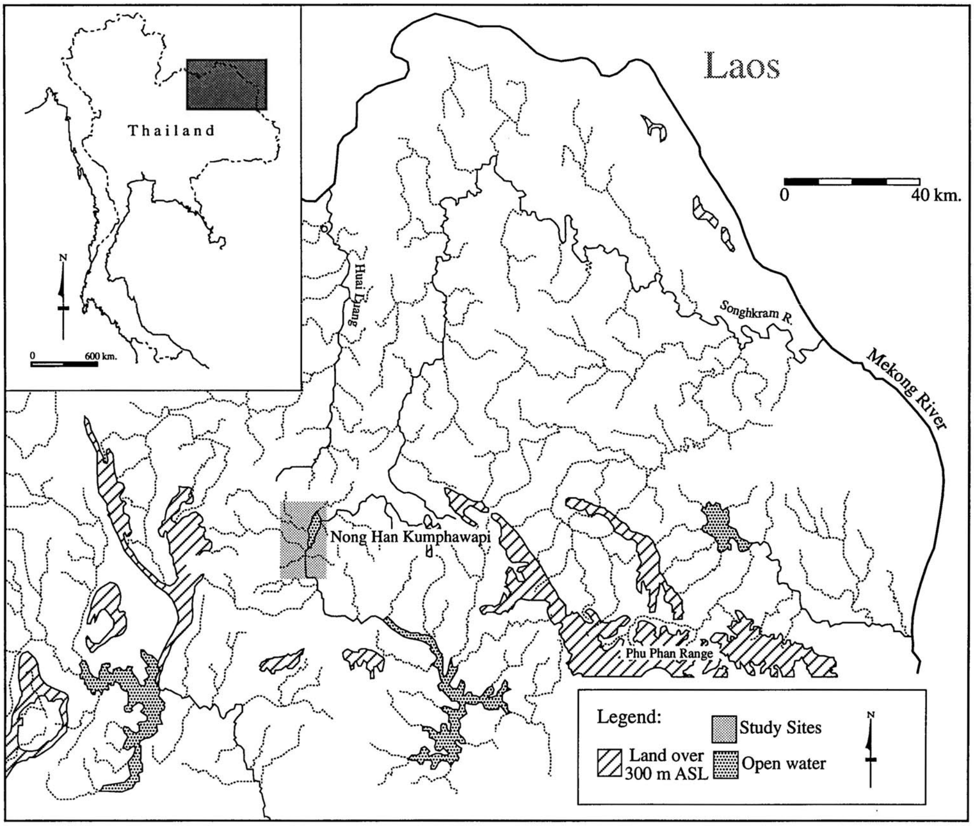

Fig. 1. Northern Khorat Plateau, Thailand, showing study site (after Higham 1989).

Sedimentary basement rocks include sandstone, siltstone, shale, conglomerate, and evaporite (Parry 1990), with the latter thought to have had a significant influence on present surface topography (Rau and Supajanya 1985). The Upper Cretaceous Maha Sarakham Formation, the uppermost formation within the Khorat Group, is characterized by beds of rock salt, up to 400 m thick which in some cases lie less than 60 m below the present land surface (Rau and Supajanya 1985). The thickening of salt anticlines within the Maha Sarakham Formation as a result of a reduction in compressive stress through river-incision has led to surface deformation and the development of salt-mounds (Rau and Supajanya 1985). Solution of salt sequences may have led to the collapse of surface structures and localized basin development (Rau and Supajanya 1985).

The modern vegetation communities of the Khorat Plateau are a product of millennia of human activity. Much of the area is used for cropping, particularly rice production. Remnant patches of original vegetation are often highly disturbed and largely restricted to areas unsuitable for rice cultivation. The dominant arboreal vegetation is a deciduous forest dominated by genera of the Dipterocarpaceae. While dipterocarps are ubiquitous across the Khorat Plateau, associations between dominant taxa vary considerably, with Dry Deciduous Forest, Mixed Deciduous Forest, Evergreen Forest, and Pine Forest recorded (White 1995).

Stott (1976) classified four principal community types based on the variable associations between dominant species. Smitinand (1989) identified three vegetation types commonly associated with the fire regimes and edaphic conditions of the northeast. These are Dry Deciduous Dipterocarp Forest, Mixed Deciduous Forest (further classified as Moist Upper Mixed, Dry Upper Mixed, or Lower Mixed), and Savanna Forest. Brief descriptions of these community types are presented here as a basis for the interpretation of fossil pollen assemblages.

Dry Deciduous Dipterocarp Forest

This is the most common forest type recorded in northeast Thailand. Structurally it can be described as an open forest with an upper canopy up to 25 m tall. This forest type is strongly deciduous and is associated with a distinct seasonal environment, frequent burning, and poor, acid or lateritic soils (Stott 1976). Dominant canopy trees include *Dipterocarpus obtusifolius, D. tuberculatus, Shorea obtusa, S. siamensis, Pterocarpus macrocarpus, Quercus kerrii,* and *Xylia kerrii.* Common subcanopy trees include *Aporusa villosa, Canarium subulatum, Dalbergia kerrii, Diospyros ehretioides, Phyllanthus embilica, Strychnos* spp., and *Symplocos cochinchinensis.* Shrub and ground-cover components include species of *Curcuma, Decaschistia, Dillenia, Habenaria, Hibiscus, Kaempferia,* and *Pectelis.* Small bamboos are also common, including species of *Arundinaria, Enkleia, Linostoma, Phoenix,* and *Pygmaeopremna.* Although ferns and orchids are not a feature of the ground flora, epiphytic forms occur frequently on canopy trees and sheltered rock surfaces. Well-represented genera include the ferns *Drynaria, Platycerium,* and *Pyrossia* and the orchids *Aerides, Ascocentrum, Bullophyllum, Cleisostoma, Dendrobium,* and *Eria.*

Mixed Deciduous Forest

Mixed Deciduous Forest consists of three community types which conform to variations in altitudinal range, physiographic setting, and climatic and edaphic conditions (Smitinand 1989). Taken as a whole, and in comparison with other community types on the Khorat, this group is characterized by considerable floristic diversity, particularly in canopy, subcanopy, and shrub strata.

Moist Upper Mixed Deciduous Forest occurs between 300 and 600 m ASL. The formation displays high diversity among canopy species, but has little floristic affinity with the diverse tropical rainforest of peninsula Thailand. Dipterocarps are generally absent, while common canopy tree species include *Adenanthera pavonina, Adina cordifolia, Afzelia xylocarpa, Albizia* spp., *Anogeissus acuminata, Bombax insigne, Dalbergia* spp., *Dillenia pentagyna, Gmeilia arborea, Largerstroemia tomentosa, Millettia leucantha, Pterocarpus macrocarpus, Tectona grandis, Terminalia* spp., and *Xylia kerrii.* Common subcanopy species include *Barringtonia racemosa, Careya arborea, Dalbergia* spp., *Diospyros* spp., *Largerstroemia* spp., *Millettia brandisiana, Peltophorum dasyrachis, Syzigium* spp., and *Vitex* spp. The shrub layer frequently consists of *Bauhinia* spp., *Croatoxylon formosum, Croton* spp., *Gardenia coronaria,* and *Mallotus* spp. Ground cover is characterized by grasses and sedges.

Dry Upper Mixed Deciduous Forest occurs on exposed ridges where potential evaporation is high and soils are generally thin and infertile. While this forest type is floristically similar to the moist upper mixed deciduous forest described above, the deciduous dipterocarps *Shorea* spp. and *Dipterocarpus* spp. are present but not strongly represented.

Lower Mixed Deciduous Forest occurs on drier, sandy or lateritic soils below 300 m altitude. Canopy composition is similar to that recorded in the Dry Upper Mixed Forest. The absence of *Tectona grandis* is a characteristic feature of this community type.

Savanna

Savanna is a form of extremely sparse woodland or wooded grasslands that is probably maintained by fire (Smitinand 1989). The arboreal component is predictably species-poor and characterized by fire-tolerant taxa such as *Acacia* spp., *Careya arborea, Mitragyna parviflora,* and *Pterocarpus macrocarpus.* Shrubs include *Bambusa arundinaceae, Carissa cochinchinensis,* and *Feroniella lucida.* By contrast with the species-poor canopy layer, the ground cover is relatively diverse, consisting principally of grasses and sedges, including *Eremochloa, Eriochloa, Eulalia, Iperata, Panicum, Sorghum, Sporobolus, Themeda,* and *Vetiveria.*

NONG HAN KUMPHAWAPI

Nong Han Kumphawapi (lat. 17° 08′ N; long. 103° 01′ E) is a large natural lake supporting an extensive herbaceous swamp and seasonally inundated floodplains (Fig. 2). Maximum water depth is less than 4 m, with considerable seasonal variation. The origin of the lake basin remains uncertain. Rau and Supajanya (1985) claim that the basin is a result of surface deformation following the solution of underlying salt sequences. Alternatively, Parry (1990), Moore (1988), and others suggest that the Kumphawapi Basin lies within a palaeochannel of the Pleistocene Mekong River, which may have run south from Nong Khai, through Kumphawapi, and then southeast, possibly following the course of the modern Chi River. This system is thought to have been abandoned following the Middle Pleistocene uplift of the Phu Phan Range and volcanic activity on the Khorat Plateau (Moore 1988).

An extensive mosaic of herbaceous swamp plants, interspersed with open water patches, exists around the margins of the lake in water depths up to about 2 m. For the most part this community is rooted on floating organic substrata. Grasses (Poaceae) and sedges (Cyperaceae) are the dominant swamp components, while other common taxa include *Eichhornia crassipes, Hydrilla verticiliata, Ipomoea aquatica, Ludwigia adscendens, Nelumbo nucifera, Nymphoides indicum, Polygonum pulcherum, Salvinia cuculata,* and fern species of the genera *Azolla,* cf. *Asplenium* and *Lygodium.*

METHODS

A 141 cm sediment core (KUM.1) was collected by "D-section" sampler from approximately 2 m water depth, in open water at an eastern, central location in the lake (Fig. 2). The core was dated by conventional radiocarbon analysis of bulk organic content at 79 cm depth and by accelerator mass spectrometer (AMS) radiocarbon analysis of pollen concentrates at depths of 141 cm, 100 cm, 80 cm,

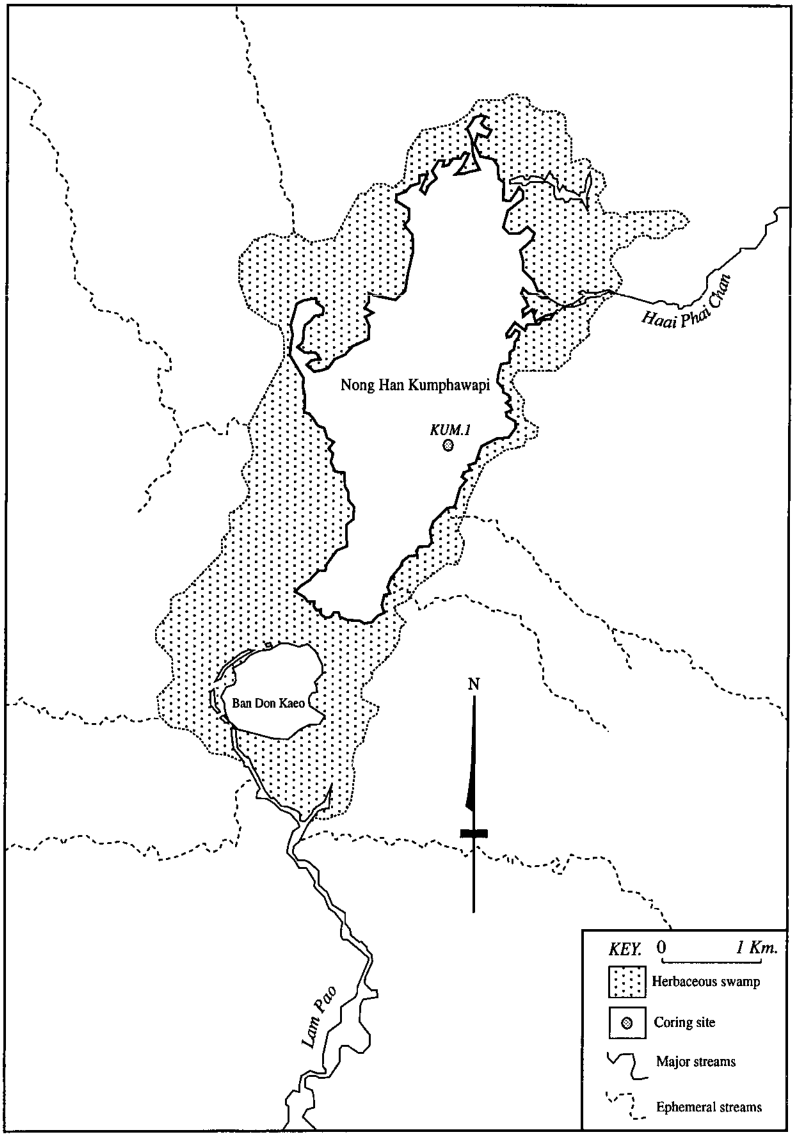

Fig. 2. Nong Han (Lake) Kumphawapi.

and 20 cm. Radiocarbon ages were calibrated using CALIB 3.0.3 (Stuiver and Reimer 1993). Stratigraphic descriptions and all microfossil preparations and analyses were made in the Centre for Palaeoecology and Palynology at Monash University.

The core was sampled at 5 to 10 cm intervals from 5 to 140 cm depth. Organic content of sediments was measured as the percentage dry weight of sample by the loss-on-ignition technique. Pollen preparations followed standard treatment by hydrochloric acid, potassium hydroxide, hydrofluoric acid, and acetylation (Faegri and Iversen 1964). For the phytolith extractions, organic material was removed by digestion in 30 percent hydrogen peroxide. Clay-sized inorganic particles were then separated from the rest of the sample through dispersion by ultrasonic probe in dilute sodium carbonate/sodium hexametaphosphate solution ("Calgon") and removed by pipetting off and discarding the supernatant, following a 3-minute settling period. This technique preserves relatively large phytoliths only. Pollen and phytolith samples were dehydrated in alcohol and mounted in optical-grade silicon oil prior to mounting onto microscope slides. Pollen and phytolith counts were performed on a light microscope at 250 × magnification or greater. Counts continued until a minimum of 100 identified pollen grains were recorded. Pollen identifications were aided by comparison with reference material held at Monash University, including extensive reference material made available at the Centre for Palaeoecology at Queens University, Belfast. Phytolith identifications were aided by reference material held at the Department of Prehistory and Archaeology at the Australian National University in Canberra and published descriptions.

Stratigraphic descriptions and analytical results are shown in pollen diagram form, where radiocarbon ages, percentage organic content, pollen, phytolith, and charcoal data are plotted against depth in core. In order to mitigate overrepresentation of local taxa, values for each taxon were calculated as a percentage of a pollen sum, which normally includes arboreal or regional taxa and excludes local or otherwise overrepresented types. In this case, it was decided to include the Poaceae in the pollen sum in order to weight realistically the representation of arboreal pollen types rather than attribute more significance to them than the total pollen counts warrant. Selected phytolith types are shown as a percentage of total identified phytoliths. Charcoal concentration values were estimated according to the two dimensional point-count method of Clark (1982), which allows an estimation of charcoal concentrations based on the projected area of charcoal in a given sample. Due to the orientation of charcoal particles on a microscope slide, this technique does not provide a direct measure of charcoal volume.

RESULTS

All analytical results are shown in the pollen diagram (Fig. 3) and the phytolith diagram (Fig. 4).

Core Stratigraphy and Radiocarbon Dates

The core contains two distinct sedimentary units with an abrupt stratigraphic boundary at 79 cm depth. The upper unit consists of organic lake muds with sparse organic macrofossil remains including plant cuticle. The lower unit consists of uniform, grey-brown clays devoid of macrofossils. Radiocarbon determinations are presented in Table 1. The pollen diagram is zoned according to significant sedimentological and palynological changes in the core.

Microfossils

Sixty-five pollen and spore types and five phytolith types were identified, with a further twenty-five pollen types grouped as "unknown." As expected, pollen and phytoliths derived from the local flora overwhelm the record, and pollen signa-

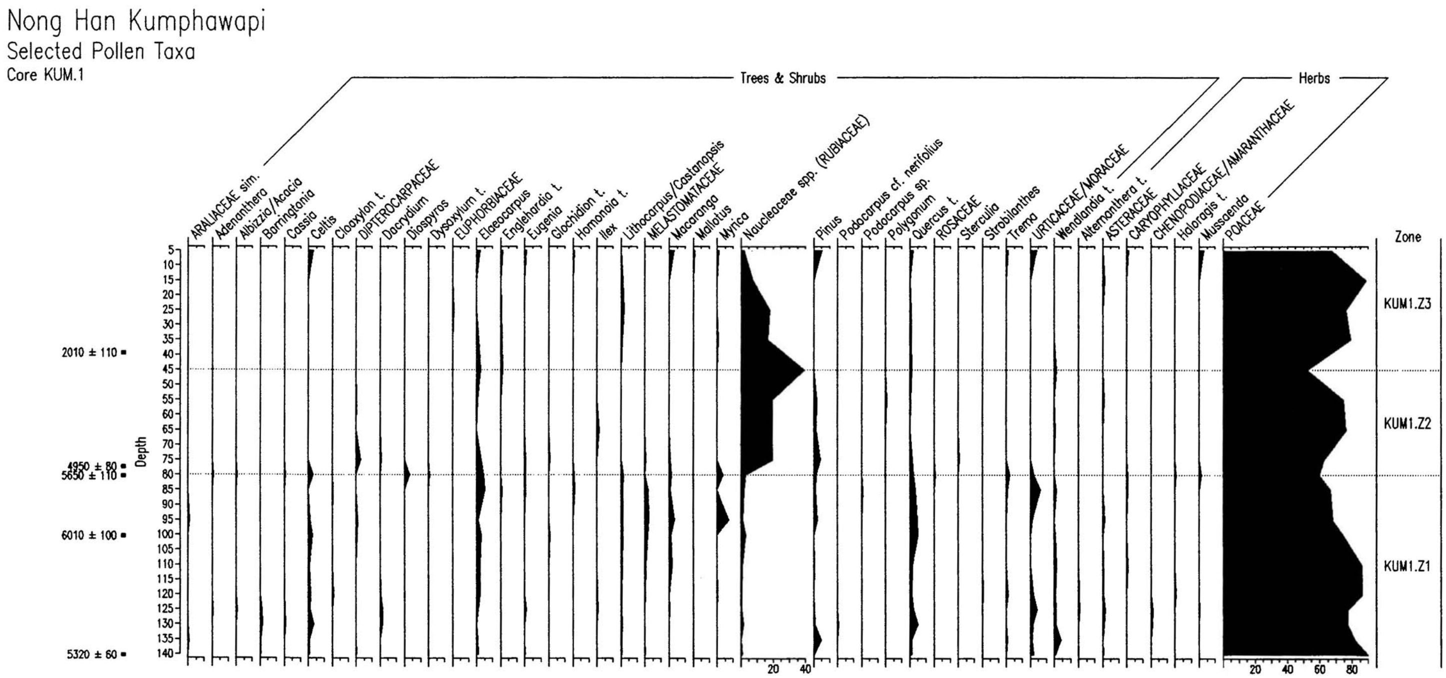

Fig. 3. Nong Han Kumphawapi, Core KUM.1: Selected arboreal and herbaceous pollen taxa.

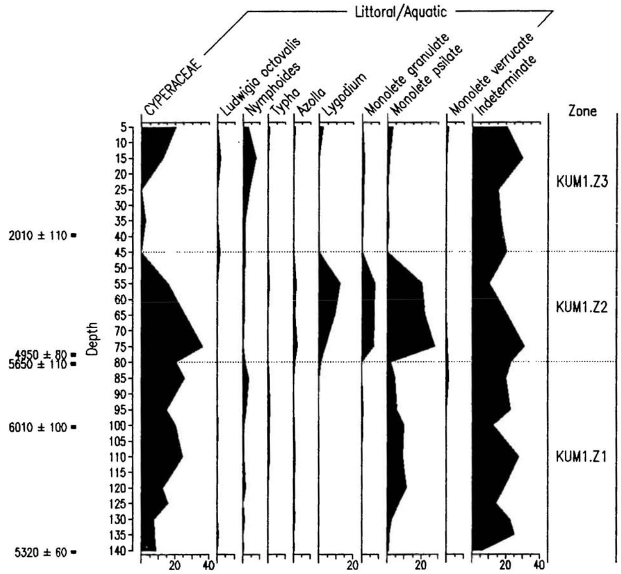

Fig. 4. Nong Han Kumphawapi, Core KUM.1: Selected aquatic pollen taxa.

tures from arboreal communities, which are more useful for determining regional patterns of environmental change, are very weak. Given this, pollen concentration estimates were based on arboreal taxa only.

Zone 1 (141–80 cm) — The organic content of sediments is low throughout this zone, with values generally less than 10 percent. Poaceae and Cyperaceae pollen types, both of which are likely to contain a strong local component, have consistently strong representation. Another local component, monolete psilate fern spores, is also consistently well represented. Regional arboreal elements, *Celtis, Elaeocarpus, Quercus, Pinus,* and Urticaceae-Moraceae, are poorly represented, while *Macaranga* and *Myrica* increase in representation towards the upper levels of the zone. Charcoal concentrations are low throughout the zone. Bulliform (undet.) and *Bambusa*-type phytoliths are well represented, compared with other sections of the core, while the *Oryza* and *Phragmites* types have moderate to low representation.

Zone 2 (80–45 cm) — This zone is characterized by high organic content of sediments (between 20 percent and 40 percent), and strong representation of the pteridophytes *Lygodium, Azolla,* and monolete fern spores. Cyperaceae values are high toward the base of the zone and steadily decrease in upper levels. Naucleaceae pollen is also very strongly represented with values generally increasing as depth decreases. Other tree and shrub taxa are poorly represented by pollen, while the herbaceaous element Asteraceae maintains consistently low values in most samples. Charcoal concentrations increase substantially and remain high throughout this zone. Values for bulliform (undet.) phytoliths are low compared to those recorded in Zone 1, while the *Bambusa* type is recorded in the basal sam-

TABLE 1. RADIOCARBON DETERMINATIONS FROM CORES KUM.1 AND KUM.2

SAMPLE DEPTH (CM)	LAB. NO.	AGE $\pm$ ERROR	CALIBRATED AGE RANGE	CALIBRATED YEARS B.P. OF MEDIAN AGE
KUM.1				
40 cm	NZA 5765	2010 $\pm$ 110	1σ: BC 157-**5 AD**-120 AD	**1945**
			2σ: BC 357-**5 AD**-244 AD	
77 cm	Wk 2366	4950 $\pm$ 80	1σ: BC 3981-3709-3649	**5659**
			2σ: BC 3951-**3709**-3543	
80 cm	NZA 5766	5650 $\pm$ 110	1σ: BC 4771-**4466**-4357	**6416**
			2σ: BC 4771-**4466**-4262	
100 cm	NZA 5768	6010 $\pm$ 100	1σ: BC 5042-**4908**-4787	**6858**
			2σ: BC 5211-**4908**-4694	
140 cm	OZB070	5320 $\pm$ 60	1σ: BC 4238-**4220-4107**-4010	–
			2σ: BC 4328-**4220-4107**-3985	
KUM.2				
305 cm	OZB074	8730 $\pm$ 70	1σ: BC 7912-**7857-7705**-7587	–
			2σ: BC 7955-**7857-7705**-7547	

Note: All determinations were by AMS on pollen concentrate except Wk 2366, which is a conventional radiocarbon analysis of a bulk sample of organic muds. Calibrated ages were calculated using CALIB 3.0.3 (Stuiver and Reimer 1993). They are reported at 1σ (68%) and 2σ (95%) confidence limits, with the median calibrated age (the age with the highest probability of being the true age of the sample) in **bold**. The true age can lie anywhere within the range given, but the probability of this decreases away from the median age. The last column converts the median age to a calibrated median age B.P. (1950 minus calibrated median age). A range of calibrated median ages is given for samples OZB070 and OZB074 because these samples' radiocarbon ages make multiple intersections with the calibration curve. Calibrated ages B.P. are not reported for these samples because these determinations are not used in the palaeoenvironmental interpretations here (see text).

ple only. Conversely, values for *Oryza* and *Phragmites* types are relatively strong compared to Zone 1.

Zone 3 (45–0 cm) — The organic content of sediments remains high in this zone, with values around 20 percent. Poaceae pollen is very strongly represented, while Cyperaceae has low values in deeper levels and increasing representation toward the surface. In contrast to Zone 2, pteridophyte spores have very low representation throughout. Strong representation of Naucleaceae at the base of the zone decreases markedly as depth decreases. *Celtis, Macaranga, Pinus,* and Urticaceae-Moraceae have relatively minor representation, with strongest values in upper levels. Strong charcoal concentrations at the base of the zone moderate toward the surface. Strong values for the *Oryza*-type phytolith and moderately strong values for the *Phragmites* type are also a feature of this zone. Bulliform (undet.) and *Bambusa*-type phytoliths maintain moderate to low representation similar to that recorded for zone 2.

DISCUSSION

Microfossils

The KUM.1 record includes a range of pollen and phytolith types that derive from local (swamp) to regional (dryland) sources, according to habitat locations

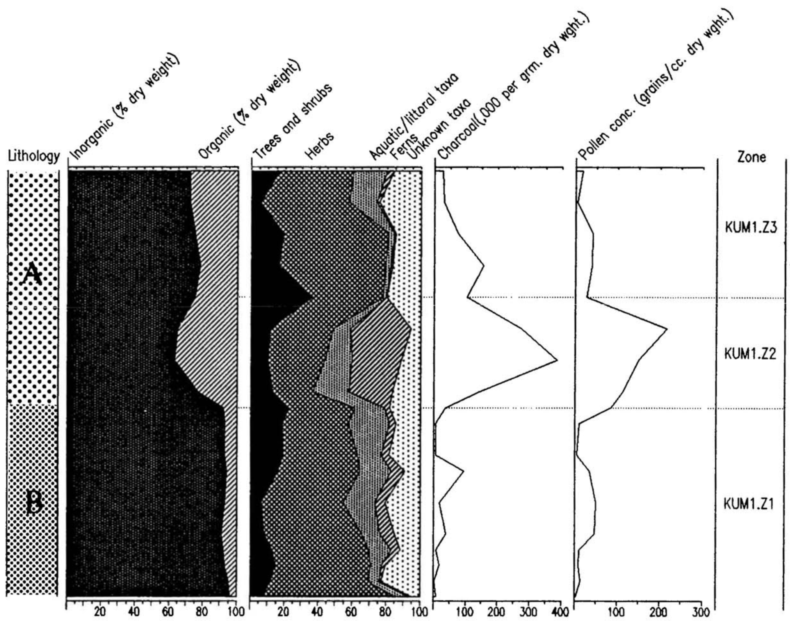

Fig. 5. Nong Han Kumphawapi, Core KUM.1: Sediment stratigraphy.

relative to the core site and the ecology of parent plant. The regional pollen component includes the arboreal pollen types Dipterocarpaceae, *Pinus, Celtis, Elaeocarpus, Macaranga,* and *Quercus.* These have low frequency representation, reflecting various combinations of modest pollen production and dispersal, distance from the core site, and the overwhelming abundance of locally produced pollen types. Pollen from the herbaceous elements Poaceae and Cyperaceae may also have regional significance, although a substantial component is likely to derive from local swamp plants as well.

The near total lack of dipterocarp pollen in the dryland pollen signature is noteworthy, given the regional importance of the Dipterocarpaceae in the deciduous forests of the Khorat. This poor pollen representation is consistent with reported vagaries of pollen production and dispersal common to the family Dipterocarpaceae (Ashton 1982). For example, Bera (1990) has shown that *Shorea robusta,* while being a prolific pollen producer, has poor representation in surrounding soils as a consequence of entomophilous pollination strategies. Ashton (1982) suggests that localized pollen dispersal and poor preservation combine to limit the value of dipterocarp pollen in fossil records.

The Naucleaceae pollen type is also likely to represent a regional or at least extralocal source. Although this taxonomic group may include marginal swamp trees (Brock 1988; Garrett-Jones 1979), the only species of this tribe recorded in the region today are forest trees or shrubs in deciduous dipterocarp forests (Stott 1976) and mixed deciduous forests (Smitinand 1989; White 1995). Members of the Naucleaceae are also known to be pioneer tree or shrub species capable of aggressive colonization of disturbed ground. *Nauclea diderichii,* for example, is a

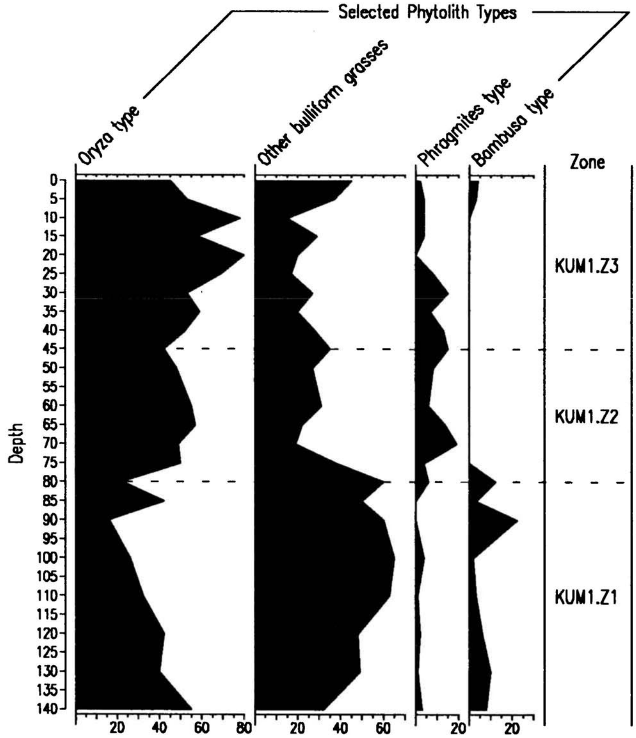

Fig. 6. KUM.1 phytolith diagram. Selected taxa.

shade-intolerant pioneer species (Riddoch et al. 1991), reported to colonize cleared areas quickly (Irvine 1961), while *Nauclea* as a genus is thought to be fire-tolerant with an "exceptional capacity for regeneration and colonization" (Garrett-Jones 1979 : 370).

Prominent local swamp elements in the pollen record include the fern taxa *Lygodium* and *Azolla,* and flowering plants *Utricularia, Ludwigia,* and *Nymphoides,* which are all present on the swamp today. The undifferentiated monolete fern spores are also likely to represent a local swamp or fringing swamp element, given the very strong representation in sections of the core and the absence of any evidence (such as a strong riparian element in the pollen assemblage) that would suggest fluvial transport of these spores from the catchment.

The inclusion of phytolith analysis as part of a larger palaeoenvironmental study of this kind is relatively new, with the notable exception of a recent study at Khok Phanom Di in south-central Thailand (Kealhofer and Piperno 1994). In the present study, four categories of bulliform grass phytolith are identified by comparison to reference material and published descriptions. The *Phragmites, Oryza,* and *Bambusa* types compare to material for these genera described elsewhere (Barnes 1990; Barnes and Okita 1993; Marumo and Yanai 1986; Sugiyama 1987; Kondo 1977; Fujiwara 1976). While Pearsall et al. (1995) consider *Oryza* phytoliths diagnostic to at least genus level, we were less confident in this regard, and this taxonomic distinction was not made in the Kumphawapi material. Therefore our *Oryza* type may represent other grass genera within the Bambusoideae (Kealhofer, pers. comm. 1995).

Radiocarbon Dates

Radiocarbon determinations show a regular increase in age with depth except for the basal determination (OZB070), which is clearly inconsistent with the other ages from the core. It is also inconsistent with an AMS determination of 8150 $\pm$ 50 (AMS: OZB074) from a similar stratigraphic context in the core KUM.2, which is yet to be analyzed fully. Because of these inconsistencies, OZB070 is discarded from the present discussion. All other determinations from KUM.1 are statistically significantly different at more than 97.5 percent confidence level (Ward and Wilson 1978).

The radiocarbon ages show that the lower grey-brown clay unit was deposited rapidly, at least in its upper 20 cm. The subsequent initiation of organic sedimentation at 79 cm is associated with a significant decline in sedimentation rates, which is reflected by a dramatic increase in pollen concentration. Increases in sedimentary charcoal from 79 cm can be partially explained by this slowing of sedimentation, but comparison of sedimentation rates according to radiocarbon results in the upper 80 cm of the core indicate that high charcoal values are real and not simply an artifact of the changes in sediment accumulation rate.

Palaeoenvironmental Interpretations

The inorganic nature of sediments and the obvious oxidation of pollen from the lower clay unit of the Kumphawapi core indicate a depositional setting that experienced intermittent drying out. This is consistent with the presence of an ephemeral littoral environment at the core site from at least 6900 until 6400 years B.P. The distinct stratigraphic boundary between this unit and the overlying organic lake muds, together with the associated palynological changes, suggest the development of permanent herbaceous swamp or lake conditions between 6400 and 5700 years B.P. Floristically, local swamp community development is most clearly evident in the increases in the representation of local swamp pteridophyte spores and *Phragmites* phytoliths.

This development of swamp conditions indicates a substantial and sustained increase in lake water level since the mid-Holocene, suggesting a climatic change from effectively drier to effectively moister conditions comparable to, and sustained until, the present day. This interpretation is consistent with climatic reconstructions from Doi Inthanon, where the onset of moister conditions is inferred at approximately 4500 (uncalibrated) years B.P. (Hastings and Liengsakul 1984). The initiation of herbaceous swamp in the Kumphawapi record is also synchronous with a short-term "humid cycle" in the northeast, which it is suggested led to the initiation of organic lake sedimentation approximately 5500 to 5200 (uncalibrated) years B.P. (Nutalaya et al. 1989). Faunal data recovered from archaeological contexts at Ban Chiang dating to this period suggest the widespread exploitation of freshwater habitats that imply permanent water resources close to the site (Higham and Kijngam 1978, 1979). While these palaeoenvironmental data are consistent with Kumphawapi evidence, Nutalaya et al. (1989) suggest that this humid period was followed by an arid phase from around 3500 (uncalibrated) years B.P. This is clearly inconsistent with the Kumphawapi record, where permanent swamp conditions appear to have been maintained throughout the late Holocene. Similarly, palaeodischarge estimates derived from broadly dated palaeochannels of the Yom River, north-central Thailand, indicate that the highest discharges were attained in the early to mid Holocene period (Bishop and Godley 1994), prior to the establishment of high lake levels at Kumphawapi.

The regional pollen record from Kumphawapi is difficult to reconcile with a simplistic climatic interpretation derived from lake level reconstructions based on local pollen and sediment changes in the core. Indeed, the development of herbaceous swamp at this site and the rise in lake level this implies may be just as credibly explained, given the available evidence, by localized changes to the lake basin or tectonic damming (Rau and Supajanya 1985) as by climatic forcing. Moreover, the sustained decline of regional wooded communities suggested by diminished arboreal pollen types since the mid-Holocene is inconsistent with a change to an effectively wetter climate. An alternative hypothesis to account for the implied changes in regional arboreal taxa involves the activities of humans in the catchment. The substantially increased representation of Naucleaeceae in the pollen record from the mid-Holocene may be indicative of catchment disturbance (although the lack of a similar trend in other regional disturbance indicators, such as *Macaranga* or *Celtis,* cannot be explained at this stage). Furthermore, increases in microscopic charcoal are interpreted as indicating a greater occurrence of fire in regional dryland communities. In short, the strong representation of Naucleaceae pollen and charcoal between approximately 6400 and less than 2000 years B.P. may indicate regional vegetation disturbance through fire. Widespread disruption to the regional vegetation may also help to explain increased water levels in Nong Han Kumphawapi, through increased surface runoff, decreased transpiration rates, and additions to ground water as a consequence of reduced vegetation cover in the lake catchment.

Although natural ignition sources for fire undoubtedly exist, it is likely that firing of the vegetation was associated with people. The earliest archaeological evidence for human occupation in northeast Thailand dates to approximately 3500 years B.P. (Higham 1989). It may be that the apparent widespread and sustained decline in regional wooded communities suggested by the preliminary pollen data presented here reflects an intensification of human activity in the area associated with the mid-Holocene occupation of the Khorat Plateau.

The microfossil record may provide an indication of early human activity in the region, but there is little indication of the development of the permanent bunded-field system of wet-rice agriculture in place today. For instance, there is no evidence of weed species common to cultivation, such as those recorded at Khok Phanom Di, southern Thailand (Maloney 1990). Bulliform grass phytoliths, especially the *Phragmites* and *Oryza* types, appear to provide an indication of local swamp development consistent with the pollen record. The *Oryza* type is likely to represent a number of genera in the Bambusoidae, including wild and domesticated strains of rice. The general increase since the mid-Holocene in this phytolith type in comparison to undifferentiated bulliform types is consistent with an increase in Bambusoid grasses, including *Oryza,* in or near the lake. However, even if the phytolith type is largely representative of *Oryza*, additional studies of the dispersal properties of phytoliths of this kind are required for assessment of the local (presumably wild rice) or regional (cultivated) significance of the assemblage.

White (1995) has suggested that the domestication of rice probably proceeded from the collection of wild forms in areas with a gentle seasonal flooding regime, as part of a larger subsistence base, to a permanent bunded field system mimicking the natural ecological conditions suitable for rice. This represents a gradual rather than an initially "intensive and environmentally transformative" process (White 1995 : 51). In our view, it is likely that the sudden regional disturbances indicated in the Kumphawapi record at approximately 6000 years B.P. are related to an intensification of human occupation. There is no evidence to suggest, nor is it deemed likely, however, that the changes at this time represent the rapid development of agriculture on a regional scale. From the available evidence, the trend toward the relative stability of the ubiquitous bunded field system in place today appears to have begun some 2000 years ago, given a substantial and sustained decline in disturbance indicators from this time. Clearly, there is now a need for detailed palaeoenvironmental records from the Khorat Plateau in order to define more closely the relationship between prehistoric people and environment in the region.

CONCLUSIONS

Microfossil analysis of a sediment core from Nong Han Kumphawapi has provided valuable palaeoenvironmental data from the mid-Holocene to the present. These data suggest a significant sedimentological and phytological change approximately 6000 years B.P., indicating the development of a productive herbaceous swamp at the core site. The causes of this environmental change are at present unclear. While the establishment of stable water levels and herbaceous swamp are consistent with some palaeoclimate estimates from the north and northeast of Thailand, the regional picture of Holocene climates remains patchy and often contradictory.

Similarly, the timing of human occupation of the Khorat Plateau and the nature of the subsistence strategies employed by the earliest settlers remain equivocal. Disturbance of regional vegetation communities from the mid-Holocene is implied by sedimentary charcoal and the strong representation of Naucleaceae pollen. Results from this study, combined with the available archaeological data, suggest that it is unlikely that a permanent bunded field system of rice cultivation was in place throughout this 6000-year sequence. Further, the record suggests that current environmental conditions, and in particular rice cultivation, may have been established gradually through the last 2000 years.

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ABSTRACT

Pollen, phytolith, and charcoal analyses are presented for a Holocene lake sediment core taken from Nong Han (Lake) Kumphawapi, Udon Thani, Northeast Thailand. Major changes appear in the record at approximately 6500 calibrated years B.P. with the establishment of permanent swamp or lake conditions at the core site and a decline in regional arboreal taxa. These changes are difficult to explain in simple climatic terms and are inconsistent with other climatic reconstructions for the region. A coincident increase in disturbance indicators in the microfossil record may reflect human activities, particularly changes to dryland vegetation through the use of fire. The technique appears to be insensitive to the development of intensive wet-rice agriculture, which almost certainly occurred during the period represented by the microfossil record. Despite this, the results indicate good potential for further detailed microfossil analyses at Nong Han Kumphawapi. KEYWORDS: palaeoenvironmental analysis, pollen, origins of rice, Thailand, Southeast Asia.